Response to referee reports

General—
We appreciate the detailed suggestions of the referees. This topic is extensive and contains some new ways of thinking about the polar wind source and the motion of low energy ions as they connect from the ionosphere to the magnetosphere. The referee comments have been quite helpful in identifying areas where further clarification is valuable. We know that the paper is long and we have tried our best to eliminate any unnecessary text and figures while at the same time adding text to make needed clarifications. We appreciate the referees' guidance in this process.

Spacecraft potential effects on the observed outflow—

Point #2 for Referee #2. The referee's comments on the subject of spacecraft potential effects on accurate measurements of H+ polar wind outflow have been important as a stimulus to further clarify our thinking on this issue. In response, we make the following points:

1) There is no doubt that positive spacecraft potentials affect the ability to make accurate measurements of the outflowing low energy ionospheric ions. This effect can be seen dramatically at high altitudes (several Earth radii) in the polar regions and in the magnetotail lobes where almost no information existed on low energy ion outflow prior to the TIDE/PSI measurements (Moore et al, 1997). This is shown in Figure 1 where the amount of measured H+ ion outflow along the magnetic field line immediately appears in the TIDE instrument just after the Plasma Source Instrument (PSI) is turned on. These observations are responsive to Referee 2's suggestions that we vary the PSI current up and down and observe the variation of the incoming H+ flux. Although this case is an off/on variation only, it does show that the H+ flux immediately appears in a region where the PSI plasma source and not the H+ density change was not the cause of the spacecraft potential change. Note also that as PSI operation continues and spacecraft potential is held to about 1 volt positive, the H+ outflowing flux is continuously visible. In other orbits across the polar cap and magnetotail lobes, where the PSI is not operating, there is almost no observed H+ outflow. The variable that is changing in this situation is not the H+ density but the spacecraft potential that is being controlled by the PSI plasma emission. Because of the dramatic nature of the appearing H+ flux at this high altitude, the acceptance of the influence of spacecraft potential for this region has been more straightforward.

2) In examining the low altitude TIDE polar wind outflow data, we have come to realize that the spacecraft potential effect is equally important at "low altitudes" of several thousand kilometers as well. In this altitude range the spacecraft potential is usually not large enough to completely obscure the measurement of the outflowing polar wind. It is, however, large enough to significantly reduce the observed flux that enters any instrument measuring low energy ions at these altitudes. The effects of spacecraft potential on the measurement of outflowing polar wind H+ ions can be seen in Figure 2 (Michael Chandler, private communication). These are modeled results which use an H+

polar wind outflow of 10 km/sec for two different temperatures, .5 and 1 eV and a density of 100 ions /cm3. Note that the density predicted from the moments calculation that would be observed on the charged spacecraft is reduced by an order of magnitude with an increase of spacecraft potential of 2 volts positive. This decrease in observed density matches the decreases in Figure 6 of the paper showing the TIDE observations. A curve based on measurements of total density and spacecraft potential using the HYDRA and EFI instruments on the POLAR spacecraft is also shown in Figure 2 (Scudder et al., 2000). Note that the spacecraft potential range of 1 to 6 volts positive corresponds to a total density range of 4000 down to10 ions/cm3.

The issue that has been raised is whether the observed H+ flux and the spacecraft potential are in fact dependent variables, i.e. that as the H+ flux (and density) increases the spacecraft potential decreases so that it is not simply the H+ flux masking effect that we have described in the paper. We think the H+ flux and spacecraft potential are fundamentally independent. The potential of the POLAR spacecraft is affected significantly by the surrounding electron density. The electron density is connected to the total ion density around the spacecraft. At 5000 km the total ion density is dominated by the O+ ions which are influenced by the sunlight, particle precipitation and joule heating in the ionosphere below the spacecraft. The typical O+ density at 5000 km is in the range of several thousand ions/cm3 (?????) while the density measured by TIDE at 5000 km is less than 100 ions/cm3 centering around about 10 ions/cm3 (See Figure 3 from Matthew's thesis). Therefore, the change of spacecraft potential at 5000 km is driven by the changing O+ density which allows spacecraft potential to be lowered or raised, thereby revealing or obscuring the H+ polar wind fluxes. The H+ ion outflow is moving up the magnetic field line, having originated in the topside ionosphere well below the spacecraft.

3) We do not think that it is a "curious result" that the polar wind H+ flux is independent of the magnetic activity level. This has been observed previously (references from the 1987 Chappell et al and Chandler papers). In addition, one expects the O+ density to vary directly with activity which will clearly affect the local density and hence the apparent fraction of the H+ distribution. This virtually requires that the apparent flux of H+ will go directly with activity, adding to any natural variation of the H+ flux. Therefore, a direct relation of O+ with activity will inevitably reduce the apparent direct dependence of H+ on activity. If after taking out the variation with floating potential, we have no remaining H+ flux increase with activity, this will be no surprise since the polar wind theory predicts that the H+ outflow is at the limiting flux possible at all time outside the plasmasphere, regardless of activity. This is because the thermal speed of H+ is close to the escape speed, and is further enhanced by the ambipolar O+ field, assuring that any H+ formed will escape on polar wind flux tubes.

Figure 1—A TIDE pass across the polar cap and magnetotail lobe with the PSI turning on during the pass.

Figure 2—The Chandler plot of simulated TIDE data and Scudder curve.

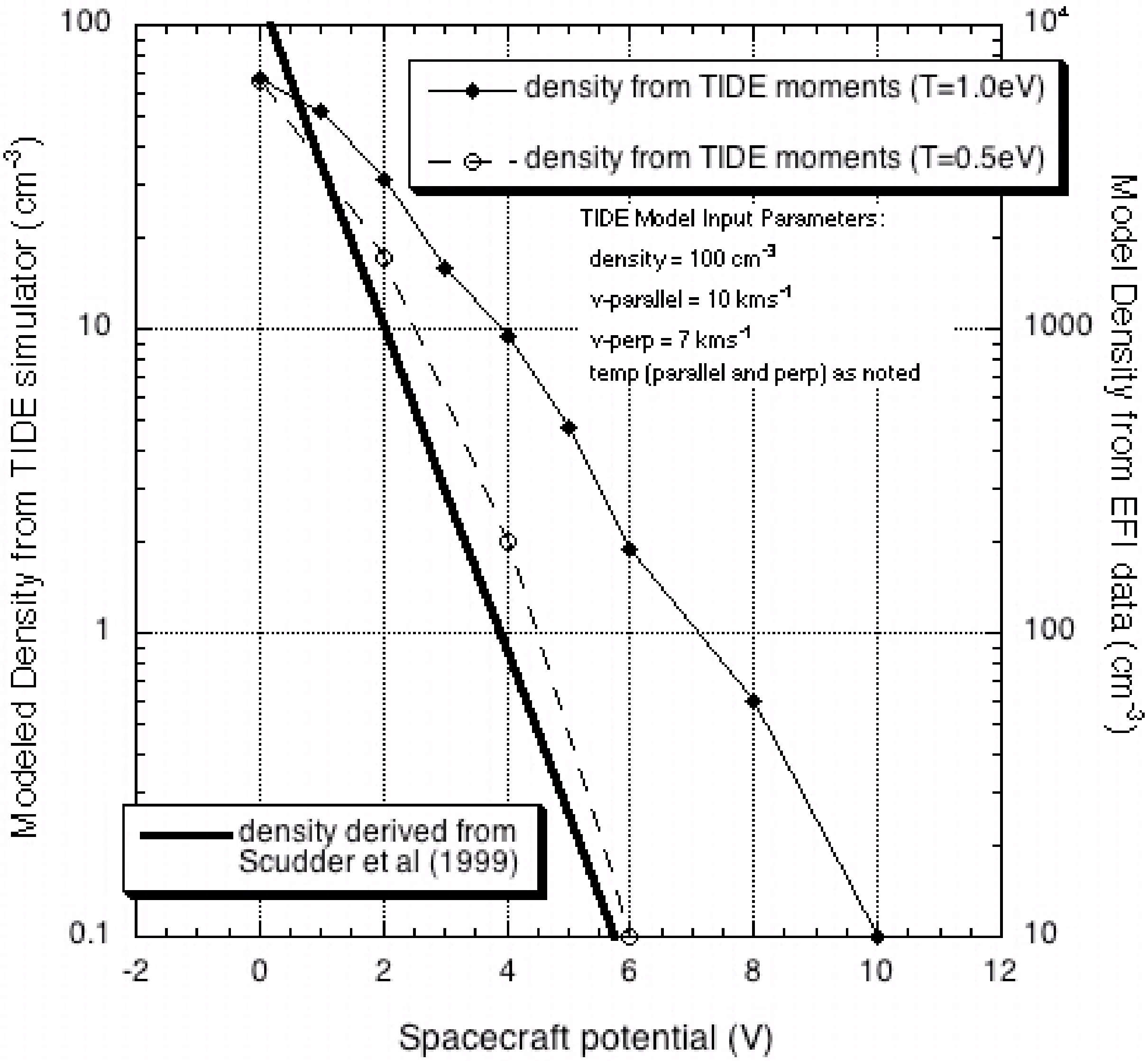

Figure 3—A plot of measured H+ density from TIDE observations at 5000 km (Matthew to provide).